

## CATALYTIC MATERIAL WITH MAGNET AND CHEMICAL REACTION DEVICE USING THE SAME

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### Abstract

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**PROBLEM TO BE SOLVED:** To provide a catalytic material which generates a gradient magnetic field near the interface of a catalyst and efficiently performs a chemical reaction using the catalyst and further, is compact and inexpensive.

**SOLUTION:** This catalytic material (1) has the catalyst (2) fixed to a permanent magnet (3).

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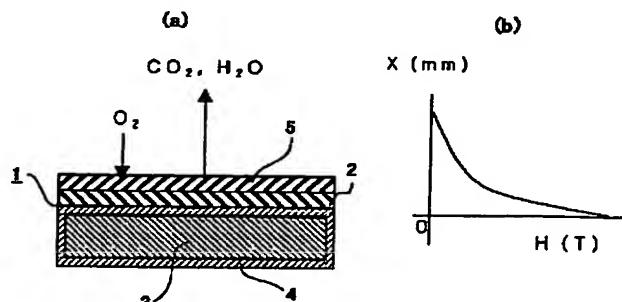
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(54)【発明の名称】 磁石を有する触媒材及びこれを用いた化学反応装置

(57)【要約】

【課題】 触媒界面近傍に勾配磁場を発生させ、触媒を用いた化学反応を効率良く行わせることができ、かつ、コンパクトで廉価に提供することのできる触媒材を提供する。

【解決手段】 永久磁石(3)に触媒(2)を固定してなる触媒材(1)。



## 【特許請求の範囲】

- 【請求項1】 永久磁石に触媒を固定し、触媒の界面近傍に勾配磁場を発生させることを特徴とする触媒材。
- 【請求項2】 永久磁石の表面に、化学的に安定で磁力線を通す物質よりなる被覆層とそれにより保持した触媒を有してなることを特徴とする触媒材。
- 【請求項3】 触媒を被覆層上に付着させたことを特徴とする請求項2記載の触媒材。

【請求項4】 化学的に安定で磁力線を通す物質と触媒の混合物で永久磁石を被覆したことを特徴とする請求項2記載の触媒材。

【請求項5】 反応に関与する物質及び反応生成物が移動しうる担体中に請求項1～4のいずれか1項記載の触媒材を担持させたことを特徴とする化学反応装置。

## 【発明の詳細な説明】

## 【0001】

【発明の属する技術分野】本発明は、化学反応を効率よく制御しうる触媒材、及びこれを用いた化学反応装置に関する。

## 【0002】

【従来の技術】従来から目的物質を効率よく製造するために、反応温度、反応圧力、反応時間、反応物質の濃度などの反応条件や適当な触媒などを選ぶことにより、化学反応を制御する方法は広く用いられてきた。近年、本発明者らは、常磁性の酸素ガスが関与する酸化、還元反応など、化学反応の前後で反応に関与する物質の磁化率が増加または減少する反応を、勾配磁場をかけることで制御する方法を開発した(特許第2034895号)。一般に、位置座標により磁場強度が変化する勾配磁場下では磁気力が発生する。単位体積あたりの物質に作用する磁気力( $F$ )は、下記式(1)の通り、体積磁化率( $\chi$ )、磁場強度( $H$ )、磁場勾配( $dH/dX$ )の積で表される(化学大辞典、4巻、167頁、共立出版(昭和44年))。

## 式(1)

$$F = \chi H (dH/dX)$$

(式中、 $F$ は単位体積あたりの磁気力、 $\chi$ は体積磁化率、 $H$ は磁場強度、 $dH/dX$ は磁場勾配を表わす。)

【0003】酸化、燃焼反応に関与する酸素ガスは常磁性で、その体積磁化率は正の大きい値(+1.5 × 10<sup>-7</sup>e.m.u.)であり、強い力で磁石に引き付けられる性質がある。殆どの物質は反磁性で、その体積磁化率は負の小さい値であり、磁石に弱く反発する。例えば、燃焼触媒を利用した有機化合物の酸化反応では、酸素ガスが常磁性で、有機化合物、炭酸ガス、水は反磁性であり、反応が進行すると酸素が消費され、磁化率は減少する。

【0004】図5に、本発明者らが先に提案した勾配磁場を利用した化学反応制御方法(前記特許)の一例として、勾配磁場中に燃焼触媒がある場合の、触媒上に付着した有機化合物の酸化反応を模式的に示した説明図を示

す。図5(a)は断面図で示すものであり、22は燃焼触媒、25は有機化合物を示し、図5(b)は触媒22が置かれている磁場の強度 $H$ と位置 $X$ の関係を示すグラフである。図5(b)のグラフのX軸の方向と位置は図5(a)の上下方向とその位置に対応しており、触媒( $X=0$ )に近づくにつれ磁場強度が緩やかに増加する勾配磁場がかけられていることを示す。このような勾配磁場中では、磁気力で酸素ガスは触媒界面に引き付けられ、反対に反応生成物の炭酸ガスや水は排除されるので、触媒上で酸化反応が促進される。

【0005】このように、反応に関与する物質を磁気力で輸送することにより、酸素ガスなどが関与する触媒反応(酸化反応)や界面反応を制御することができる。この方法で効率よく反応を行わせるためには、触媒近傍のみ、すなわち、反応サイトにできるだけ近い場所で、大きな磁気力を発生させることが非常に重要である。式(1)に示したように、一般に磁気力は磁場強度と勾配の積、 $H (dH/dX)$ に比例するので、上記の磁気力を利用した化学反応の制御を有効に行うためには、触媒近傍で $H (dH/dX)$ が大きな値をもつ、急峻な勾配磁場を発生させることが望ましい。しかし、従来からある電磁石などを利用した勾配磁場発生法による場合には、装置が大規模なものとなり、高価であり、大掛りな電源等も必要で、工場など実際の現場での使用に問題があった。またこのような装置では、実際に反応が進行する触媒界面近傍のみに急峻な勾配磁場を発生させることが困難であった。

## 【0006】

【発明が解決しようとする課題】したがって本発明は、触媒界面近傍に勾配磁場を発生させ、触媒を用いた化学反応を効率良く行わせることができ、かつ、コンパクトで廉価に提供することのできる触媒材を提供することを目的とする。さらに本発明は、勾配磁場中の触媒界面で、効率良く反応を行わせることができる化学反応装置を提供することを目的とする。

## 【0007】

【課題を解決するための手段】本発明者らは、触媒界面に急峻な勾配磁場を発生させる方法について鋭意研究を重ねた結果、ネオジウム-鉄-ホウ素系など強力な永久磁石の表面に直接触媒を固定したり、永久磁石を化学的に安定で磁力線を通す物質で覆って、さらにその表面に触媒を付着させたりすると、上記の化学反応制御を効率よく行うことのできる急峻な勾配磁場を、触媒界面近傍に作りうることを見出した。本発明はこの知見に基づきなされた。すなわち本発明は、(1)永久磁石に触媒を固定し、触媒の界面近傍に勾配磁場を発生させることを特徴とする触媒材、(2)永久磁石の表面に、化学的に安定で磁力線を通す物質よりなる被覆層とそれにより保持した触媒を有してなることを特徴とする触媒材、(3)触媒を被覆層上に付着させたことを特徴とする

(2) 項記載の触媒材、(4) 化学的に安定で磁力線を通す物質と触媒の混合物で永久磁石を被覆したことを特徴とする(2) 項記載の触媒材、及び(5) 反応に関与する物質及び反応生成物が移動しうる担体中に(1)～(4) 項のいずれか1 項記載の触媒材を担持させたことを特徴とする化学反応装置を提供するものである。

## 【0008】

【発明の実施の形態】本発明の触媒材は、永久磁石及び触媒、並びに必要に応じて永久磁石を被覆し触媒を保持する被覆層を有してなる。本発明の触媒材によって発生する「勾配磁場」とは、磁場強度の分布が、触媒から離れるにつれ減少していく関係を有する磁場をいう。本発明において、触媒の界面近傍とは、触媒の界面の位置を含むものである。本発明においては触媒の界面近傍に、特に急峻な勾配磁場を発生させることができ。例えば、触媒材を用いる化学反応の種類や環境によても異なるが、式(1) の ( $dH / dX$ ) が  $0.1 \text{ T/cm}$  以上の磁場を発生させることができ、このためには所望の勾配磁場を形成しうる永久磁石が適宜選択される。具体的には上記のネオジウム一鉄一ホウ素磁石のほか、サマリウム・コバルト磁石などを用いることができる。永久磁石のサイズ、形状は使用目的等に応じて適宜選択することができる。本発明において、用いる永久磁石が、触媒材を用いる化学反応の環境において安定な場合には、永久磁石の表面に直接、触媒を付着させ、本発明の触媒材とすることができる。また、永久磁石自体が使用環境で化学的に変化しやすいような場合には、磁力線を通して、かつ、化学的に安定な物質で永久磁石表面を覆うことが好ましい。「磁力線を通す」とは、被覆層通過後の磁場強度がゼロでないことであるが、好ましくは被覆層通過前の90%以上であることをいい、「化学的に安定」とは、触媒材を使用する環境において、被覆層の成分が実質的に反応に関与せず、変化しないことをいう。磁石表面を被覆する物質は、触媒材を使用する環境などに応じ適宜選択されるが、例えばプラスチックスやセラミクス、ガラスなどが挙げられる。被覆層の厚さも適宜設定されるが、被覆層が薄いほうが急峻な勾配磁場が得られ、永久磁石表面により近い位置に触媒を配置することできるため、好ましくは1 mm以下、さらに好ましくは0.01～0.1 mmとする。

【0009】本発明の触媒材の第一の態様は、必要に応じ接着用の物質(化学的に安定で磁力線を通すもの)を用いるなどして、永久磁石に直接、触媒を付着、固定させたものである。本発明の触媒材の第二の態様は、上記被覆層を形成したのち、上記と同様に触媒を被覆層表面に付着、固定させたものである。また第三の態様としては、触媒を混合した被覆層形成物質で磁石表面を被覆することにより、触媒を被覆層中に含有させたものがある。さらに、別の態様として、被覆層上に触媒と触媒担持物質からなる別の層を形成してもよい。別の層を形成

する場合の触媒担持物質は、担持させる触媒の種類や触媒材の使用環境などにより適宜選択できる。

【0010】本発明において用いる触媒の種類は、上記のように永久磁石に固定しうるか、被覆層もしくは被覆層中に担持させることのできるものであれば、例えば光触媒、燃焼触媒など、特に制限はない。本発明の触媒材によれば、反応場全体ではなく、触媒を用いる反応において触媒の界面近傍に勾配磁場を形成できるため、触媒作用を促進させることができる。本発明の触媒材を用いれば、反応の進行とともに体積磁化率が低下する化学反応が促進され、反応の進行とともに体積磁化率が増加する化学反応が抑制されるため、例えば酸化反応、燃焼反応などの反応を効率よく行わせることができる。このような触媒材として、具体的には白金などの燃焼触媒、酸化チタンや酸化亜鉛などの光触媒などを付着、固定した触媒材が挙げられる。また、用いる触媒の粒径または触媒含有層の厚さは、特に制限はないが、好ましくは0.1 mm以下である。

【0011】本発明の触媒材の使用方法は、目的とする反応や使用環境により適宜選択しうるが、例えば、触媒材を反応媒体中に分散させるほか、担体に担持させて使用することもできる。触媒材を担持させる担体は、目的とする化学反応に関与する物質や反応生成物がその中を移動できるものであり、必要に応じポーラスな物質(例えばセラミクス多孔体、グラファイト、多孔質のプラスチックスなど)を使用するなどして前記の移動を可能とする。このように触媒材を、担体中に配置することで、一定空間内の触媒の界面面積を広げることができ、さらに効率良く反応を制御することが可能になる。上記担体に担持させた触媒材の使用方法としては、例えば担体中に直接反応原料や酸素などを供給して触媒界面で反応を行わせる、反応容器中の反応場に担体に担持させた触媒材を分散して配置するなどがあげられる。触媒材は、担体を用いる場合、用いない場合のいずれも、反応場に通常、その反応において用いる当該触媒の量が存在することとなるよう、数量等を適宜調整する。また、複数の触媒材の分散、配置については、相互の磁場が影響しても必要な勾配磁場が形成されているような触媒材の分散、配置とするものである。また、まず磁化していない磁石材に触媒を固定したものを担持物質内に分散させて配置し、その後、電磁石などにより磁場をかけることで磁化させて適切な勾配磁場が形成された触媒材、さらにはこの触媒材を配置した化学反応装置とすることもできる。

【0012】本発明の化学反応装置は、上記の担体に担持させた触媒材を有することを特徴とする。本発明の化学反応装置は通常の反応容器、反応原料供給手段、反応生成物回収手段などを有するが、これらには特に制限はない。化学反応装置における担体に担持させた触媒材の配置などは、上記の使用方法となるよう適宜設定される。

【0013】本発明の触媒材、及びこれを用いた化学反応装置は、反応前後に磁化率がより大きく減少する化学反応に対し、より有効である。

#### 【0014】

【実施例】次に本発明の実施例につき図面を参照してさらに詳細に説明する。

##### 実施例1

図1は本発明の触媒材の一実施例を示す説明図である。図1(a)は永久磁石3を被覆する被覆層4の表面に触媒2を付着、固定させた触媒材1と、その表面の有機化合物5を断面図で示したものであり、図1(b)は触媒材1における磁場の強度Hと位置Xの関係を模式的に示すグラフである。図1には薄膜状の触媒2を付着させたものを示したが、触媒の形状は粒状等であってもよく、被覆層上に分散して付着するものでもよい。図1(b)のグラフのX軸は図1(a)の上下方向の、磁石3の界面からの距離であり、この距離について図1(a)と図1(b)は対応しており、図に示すように、触媒2と有機化合物5に近づくにつれ磁場強度が増加する、急峻な勾配磁場が発生している。

【0015】上記の触媒界面近傍の磁場強度分布を示すものとして、ネオマックス（商品名、住友特殊金属社製、ネオジウム-鉄-ホウ素系）の厚さが1cmで縦2cm、横3cmの直方体のもの、及び厚さが3cmで縦2cm、横3cmの直方体のもの、2種類の永久磁石の磁場強度分布の測定結果を図2に示す。図2(i)に永久磁石3近傍の磁場強度測定におけるN極、S極及びX軸方向を示した。X軸の原点は磁石面（磁石のN極側の上面）の中心である。図2(ロ)は磁石3の厚さが1cm、図2(ハ)は厚さが3cmの場合の磁場強度の位置分布である。いずれの場合も、永久磁石3の表面から遠ざかるにつれ、磁場強度Hは急激に減少している。永久磁石の表面近傍での磁場強度と勾配の積、 $H(dH/dX)$ は、厚さが1cmの永久磁石では $0.082T^2/cm$ ( $8.2kG^2/cm$ )、厚さが3cmの永久磁石では約 $0.24T^2/cm$ (約 $24kG^2/cm$ )である。これらの値は電磁石で得られる勾配磁場の値とほぼ同程度である。ガウスマータのセンサーの厚みが1mmであるため、永久磁石表面に極めて近い位置での磁場強度の正確な計測是不可能であったが、磁場強度(H)は磁石からの距離(X)のn乗の逆数になるため（磁石の形状にもよるが一般にnは1～3である）、磁石表面の極近傍においては実際はもっと大きい値であると考えられる。

【0016】次に厚さ0.03mmのポリエチレンフィルムでそれぞれの永久磁石を覆った場合についても測定を行ったところ、図2(ロ)、(ハ)と変わらない結果が得られた。したがって、このポリエチレンフィルム上に、例えば白金、酸化チタンなどの粒子を分散して付着させた場合、あるいは図1に示した触媒材のように、こ

のような触媒を磁力線をほぼ透過しうる薄膜上に付着させた場合に、触媒表面近傍に図2(ロ)、(ハ)に示される急峻な勾配磁場が存在することがわかる。

【0017】図2(ロ)又は(ハ)に示される勾配磁場がある場合、図1(a)中に矢印で示したように、酸素等の常磁性の物質は触媒表面（触媒と有機化合物の界面）に引きつけられ、水や二酸化炭素などの反磁性の物質は触媒表面から排除されることとなる勾配磁場の作用自体は、特許第2034895号の明細書の記載からも分かる。これにより、酸化反応等の反応に必要な常磁性の酸素ガスの供給が促進され、磁化率が減少する化学反応が触媒表面で促進され、還元反応等の反応に伴って磁化率が増加する化学反応が抑制されるように、反応が制御されることとなる。

#### 【0018】実施例2

次に円筒型の永久磁石を用いた本発明の触媒材を2個配置した場合の磁場強度の位置分布を示す。図3(i)は2個の永久磁石3（ネオマックス、直径3mm、高さ2mm）の配置を示す説明図である。永久磁石が小さい場合、正確な磁場強度の位置分布の計測は非常に困難であるため、図3(i)に示す、円筒状の永久磁石2個が5mm離れて存在する場合の磁場強度分布について計算した。Y軸は高さ方向の位置であり、X軸はY軸と垂直方向の位置である。図3(ロ)は永久磁石近傍の磁場強度Hと位置Xの関係を示すグラフであり、Y=1.5mmにおける磁場強度の分布である。永久磁石3の近傍で急峻な勾配磁場 $0.31T^2/cm$ ( $31kG^2/cm$ )が発生する。例えばこの磁石表面で酸素ガスに作用する磁気引力は、式(1)から $4.6\mu N/cm^3$ ( $4.6$ ダイン/ $cm^3$ )と見積もられる。この円筒型永久磁石を触媒厚さ0.03mmのポリエチレンフィルムで覆っても変わらない結果が得られた。

#### 【0019】実施例3

図4は、本発明の他の実施例である触媒材を、担体に担持させた状態を模式的に示した断面図である。触媒材11における永久磁石13は球型のものであり、表面に触媒を含有する被覆層12を有する。この触媒材11は、担体14中に分散して担持されている。担体14は例えばボーラスな物質で、化学反応に関与する物質や反応生成物がその中を移動することができるものである。図4においては担体中に多数の粒状の触媒材が分散している状態を、その一部を拡大した断面図で示した。磁力線を透過しうるように触媒の粒径や量、被覆層の膜厚などを適宜選択して形成した被覆層12は、永久磁石の形成する勾配磁場に悪影響を及ぼすことはなく、実施例1、2で示したと同様に触媒界面近傍には急峻な勾配磁場が形成された。なお、上記の担体に担持させた触媒材を用いた化学反応装置の実施例として、担体と触媒材のほか、反応容器や反応原料の供給手段、反応生成物の回収手段を有し、上記担体に担持させた触媒材は反応容器中に充

填して担体中に反応原料や酸素などを直接供給するものを作成した。

#### 【0020】

【発明の効果】以上説明したように、本発明の触媒材は、磁石による勾配磁場と触媒を組み合わせるという全く新しい発想で、実際に反応が進行する触媒界面近傍に勾配磁場、特に急峻な勾配磁場を容易に発生させ、触媒作用を促進させ、効率良く化学反応を行わせることができる。本発明においては大掛かりな装置や電源などを必要とせず、手軽に簡単に、急峻な勾配磁場を触媒界面近傍に発生させることができ、酸化反応などを効率良く行わせることができるという優れた作用を奏する。また本発明の触媒材及びこれを用いた化学反応装置はコンパクトに構成でき、種々の環境での実用が可能である。

#### 【図面の簡単な説明】

【図1】(a)は本発明の触媒材の一実施例を断面図で示す説明図であり、(b)は(a)の触媒材の永久磁石表面からの距離Xと磁場強度Hの関係を模式的に示すグラフである。

【図2】(イ)は図1の触媒材に用いた永久磁石の磁場強度測定における、永久磁石のN極、S極及びX軸を示

す説明図であり、(ロ)は厚さ1cmの永久磁石の磁場強度測定結果を示すグラフ、(ハ)は厚さ3cmの永久磁石の磁場強度測定結果を示すグラフである。

【図3】(イ)は円筒型永久磁石2個を用いた触媒材の磁場強度分布における永久磁石の位置とN極、S極及びX軸を示す説明図であり、(ロ)は磁場強度分布を示すグラフである。

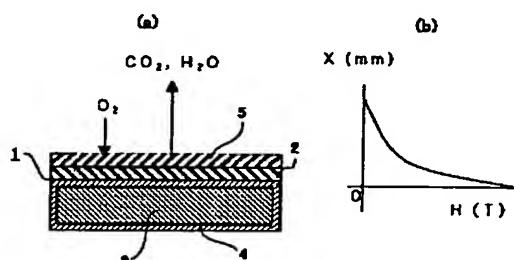
【図4】担体に担持された本発明の触媒材の一実施例を断面図で示す説明図である。

【図5】従来の勾配磁場による化学反応制御の説明図であり、(ア)は触媒と有機化合物を断面で示す説明図、(ブ)は(ア)の触媒からの距離Xと磁場強度Hの関係を示すグラフである。

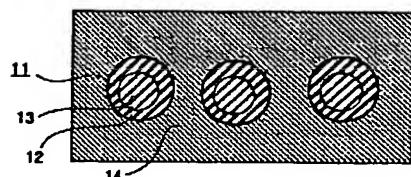
#### 【符号の説明】

- 1、11 触媒材
- 2、22 触媒
- 3、13 永久磁石
- 4 被覆層
- 5、25 有機化合物
- 12 触媒含有被覆層
- 14 担体

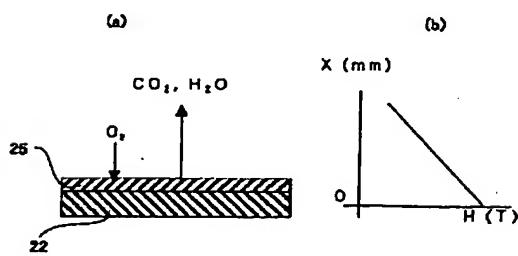
【図1】



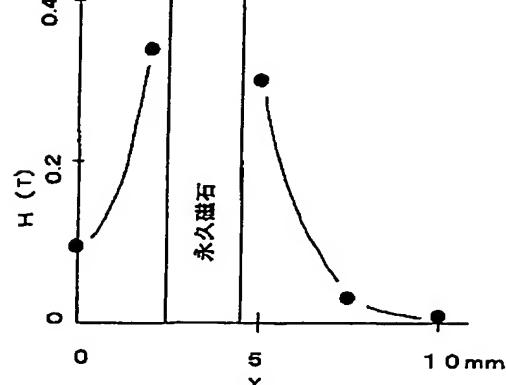
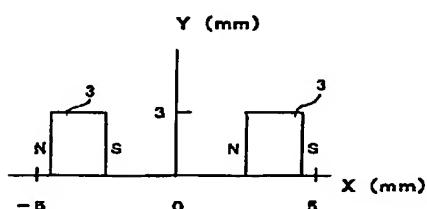
【図4】



【図5】

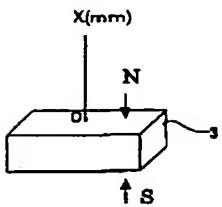


【図3】

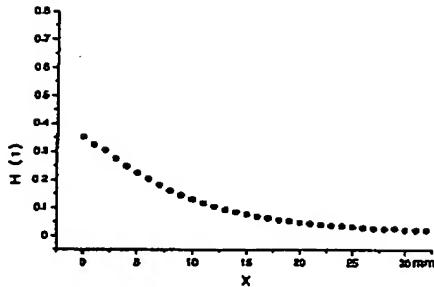


【図2】

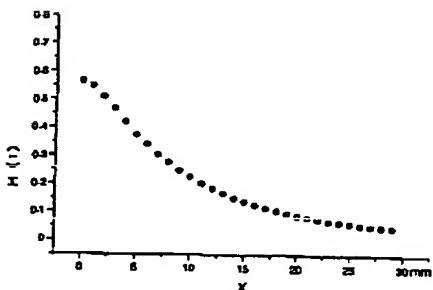
(イ)



(ロ)



(ハ)



## フロントページの続き

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**CLAIMS**

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**[Claim(s)]**

[Claim 1] Catalyst material characterized by fixing a catalyst to a permanent magnet and generating a gradient magnetic field near the interface of a catalyst.

[Claim 2] Catalyst material characterized by coming to have the enveloping layer which consists of matter which is chemically stable and lets line of magnetic force pass on the surface of a permanent magnet, and the catalyst which this held.

[Claim 3] Catalyst material according to claim 2 characterized by making a catalyst adhere on an enveloping layer.

[Claim 4] Catalyst material according to claim 2 characterized by covering a permanent magnet with the matter which is chemically stable and lets line of magnetic force pass, and the mixture of a catalyst.

[Claim 5] Chemical reaction equipment characterized by making the catalyst material of claim 1-4 given in any 1 term support in the support which the matter and resultant which participate in a reaction can move.

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**DETAILED DESCRIPTION**

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**[Detailed Description of the Invention]****[0001]**

[Field of the Invention] This invention relates to the catalyst material which can control a chemical reaction efficiently, and the chemical reaction equipment using this.

**[0002]**

[Description of the Prior Art] In order to manufacture the quality of the specified substance efficiently from the former, the approach of controlling a chemical reaction has been widely used by choosing reaction conditions, suitable catalysts, etc. of reaction temperature, reaction pressure, reaction time, and reacting matter, such as concentration. In recent years, this invention persons developed the approach of controlling reactions for which the magnetic susceptibility of the matter which participates in a reaction before and after a chemical reaction increases or decreases, such as oxidation, a reduction reaction, etc. in which the oxygen gas of a paramagnetism participates, by applying a gradient magnetic field (patent No. 2034895). Generally, magnetic force occurs under the gradient magnetic field where magnetic field strength changes with position coordinates. The magnetic force (F) which acts on the matter per unit volume is expressed with the product of bulk susceptibility ( $\chi$ ), magnetic field strength (H), and a field gradient ( $dH/dX$ ) as the following type (1) (a chemistry great dictionary, four volumes, 167 pages, KYORITSU SHUPPAN (Showa 44)).

Formula (1)

$$F = \chi H (dH/dX)$$

(Among a formula, in F, bulk susceptibility and H express magnetic field strength, and, as for  $dH/dX$ , the magnetic force per unit volume and  $\chi$  express a field gradient.)

[0003] The oxygen gas which participates in oxidation and a combustion reaction is a paramagnetism, and the bulk susceptibility is a forward large value ( $+1.5 \times 10^{-7}$ e.m.u.), and has the property drawn to a magnet by the strong force. Almost all matter is diamagnetism, and the bulk susceptibility is a negative small value, and is weakly \*\*\*\*ed to a magnet. For example, in the oxidation reaction using a combustion catalyst of an organic compound, the oxygen gas of an organic compound, carbon dioxide gas, and water is diamagnetism in a paramagnetism, if a reaction advances, oxygen will be consumed and magnetic susceptibility will decrease.

[0004] The explanatory view having shown typically oxidation reaction of the organic compound which adhered on the catalyst in case a combustion catalyst is all over a gradient magnetic field as an example of the chemical reaction control approach (said patent) which used for drawing 5 the gradient magnetic field which this invention persons proposed previously is shown. A sectional view shows drawing 5 (a), 22 shows a combustion catalyst, 25 shows an organic compound, and drawing 5 (b) is a graph which shows the reinforcement H of the magnetic field on which the catalyst 22 is put, and the relation of a location X. It is shown that the gradient magnetic field which magnetic field strength increases gently is applied as X shaft orientation and the location of a graph of drawing 5 (b) are equivalent to the vertical direction and location of drawing 5 R > 5 (a) and a catalyst (X = 0) is approached. All over such a gradient magnetic field, since oxygen gas is drawn to a catalyst interface with magnetic force and carbon dioxide gas and water of a resultant are eliminated on the contrary, oxidation reaction is promoted on a catalyst.

[0005] Thus, the catalytic reaction (oxidation reaction) and the interface reaction in which oxygen gas etc. participates are controllable by conveying the matter which participates in a reaction with

magnetic force. In order to make it react efficiently by this approach, it is the nearest possible location only near the catalyst (i.e., a reaction site), and it is very important to generate big magnetic force. Since magnetic force is generally proportional to the product of magnetic field strength and inclination, and  $H$  ( $dH/dX$ ) as shown in the formula (1), in order to control the chemical reaction using the above-mentioned magnetic force effectively, it is desirable to generate the steep gradient magnetic field in which  $H$  ( $dH/dX$ ) has a big value near the catalyst. However, when based on the gradient magnetic field evolution method which used a certain electromagnet etc. from the former, equipment became large-scale, the expensive and large-scale power source etc. was required, and the problem was in use in actual sites, such as works. Moreover, it was difficult to generate a steep gradient magnetic field with such equipment only near [ where a reaction actually advances ] the catalyst interface.

[0006]

[Problem(s) to be Solved by the Invention] Therefore, this invention can generate a gradient magnetic field near the catalyst interface, and can make the chemical reaction using a catalyst perform efficiently, and aims at offering the catalyst material which it can be compact and can be offered at a low price. Furthermore, this invention is a catalyst interface in a gradient magnetic field, and aims at offering the chemical reaction equipment which can be made to react efficiently.

[0007]

[Means for Solving the Problem] The result of having repeated research wholeheartedly about the approach this invention persons make a catalyst interface generate a steep gradient magnetic field, If a direct catalyst is fixed to the front face of powerful permanent magnets, such as a neodium-iron-boron system, or it covers by the matter which is chemically stable in a permanent magnet and lets line of magnetic force pass and a catalyst is made to adhere to the front face further It found out that the steep gradient magnetic field which can perform the above-mentioned chemical reaction control efficiently could be made near the catalyst interface. This invention was made based on this knowledge. Namely, the catalyst material characterized by for this invention fixing a catalyst to (1) permanent magnet, and generating a gradient magnetic field near the interface of a catalyst, (2) Catalyst material characterized by coming to have the enveloping layer which consists of matter which is chemically stable and lets line of magnetic force pass on the surface of a permanent magnet, and the catalyst which this held, (3) Catalyst material given in (2) terms characterized by making a catalyst adhere on an enveloping layer, (4) Catalyst material given in (2) terms characterized by covering a permanent magnet with the matter which is chemically stable and lets line of magnetic force pass, and the mixture of a catalyst, And the chemical reaction equipment characterized by making the catalyst material of (1) - (4) term given in any 1 term support in the support which the matter and resultant which participate in (5) reactions can move is offered.

[0008]

[Embodiment of the Invention] The catalyst material of this invention comes to have the enveloping layer which covers a permanent magnet if needed in a permanent magnet and a catalyst, and a list, and holds a catalyst. The magnetic field where, as for the "gradient magnetic field" generated by the catalyst material of this invention, distribution of magnetic field strength has the relation in which it decreases as it separates from a catalyst is said. In this invention, the location of the interface of a catalyst is included near the interface of a catalyst. In this invention, a steep gradient magnetic field can be especially generated near the interface of a catalyst. For example, although it changes also with the classes and environments of a chemical reaction using catalyst material, ( $dH/dX$ ) of a formula (1) can generate a magnetic field  $0.1\text{ T}$  [ $/\text{cm}$ ] or more, and the permanent magnet which for that can form a desired gradient magnetic field is chosen suitably. Specifically, a samarium cobalt magnet besides the above-mentioned neodium-iron-boron magnet etc. can be used. The size of a permanent magnet and a configuration can be suitably chosen according to the purpose of use etc. In this invention, in the environment of a chemical reaction using catalyst material, when stable, the permanent magnet to be used makes a catalyst adhere directly on the surface of a permanent magnet, and can consider as the catalyst material of this invention. Moreover, when the permanent magnet itself tends to change chemically by the operating environment, it is desirable to cover a permanent magnet front face for line of magnetic force by the stable matter through and chemically. Although it is that the magnetic field strength after enveloping layer passage is not zero with "it lets line of

magnetic force pass", it says that it is 90% or more before enveloping layer passage preferably, and in the environment which uses catalyst material, the component of an enveloping layer does not participate in a reaction substantially, but "it is stability chemically" means not changing. Although the matter which covers a magnet front face is suitably chosen according to the environment which uses catalyst material, plastics, ceramics, glass, etc. are mentioned, for example. Although the thickness of an enveloping layer is also set up suitably, the gradient magnetic field where the one where an enveloping layer is thinner is steep is obtained, and since [ which arranges a catalyst in a near location by the permanent magnet front face ] things can be carried out, 0.01-0.1mm costs 1mm or less still more preferably preferably.

[0009] The matter for adhesion (what is chemically stable and lets line of magnetic force pass) is used for the first mode of the catalyst material of this invention if needed, and it makes a catalyst adhere and fix to a permanent magnet directly. The second mode of the catalyst material of this invention makes a catalyst adhere and fix to an enveloping layer front face like the above, after forming the above-mentioned enveloping layer. Moreover, there is a thing which made the catalyst contain in an enveloping layer by covering a magnet front face with the enveloping layer morphogenetic substance which mixed the catalyst as the third mode. Furthermore, another layer which consists of a catalyst and catalyst support matter may be formed on an enveloping layer as another mode. The catalyst support matter in the case of forming another layer can be suitably chosen by a class of catalyst, an operating environment of catalyst material, etc. which are made to support.

[0010] If the class of catalyst used in this invention can be fixed to a permanent magnet as mentioned above or it can be made to support on an enveloping layer or in an enveloping layer, especially a limit will not have a photocatalyst, a combustion catalyst, etc., for example. According to the catalyst material of this invention, since a gradient magnetic field can be formed near the interface of a catalyst in the reaction using not the whole reaction place but a catalyst, a catalysis can be promoted. The chemical reaction to which bulk susceptibility falls with advance of a reaction is promoted, and since the chemical reaction which bulk susceptibility increases with advance of a reaction is controlled, oxidation reaction, a combustion reaction, etc. can be made to react efficiently, if the catalyst material of this invention is used. The catalyst material which adhered and specifically fixed photocatalysts, such as combustion catalysts, such as platinum, titanium oxide, and a zinc oxide, etc. as such catalyst material is mentioned. Moreover, the particle size of the catalyst to be used or the thickness of a catalyst content layer is 0.1mm or less preferably, although there is especially no limit.

[0011] Although it can choose suitably by the reaction and operating environment which are made into the purpose, catalyst material is distributed in a reaction medium, and also it can also be used, for example, making support able to support the operation of the catalyst material of this invention. The matter and resultant which participate in the target chemical reaction can move in the inside of it, and the support which makes catalyst material support enables the aforementioned migration using porous matter (for example, a ceramics porous body, graphite, porous plastics, etc.) if needed. Thus, it becomes possible to be able to extend the interfacial area of the catalyst in fixed space, and to control a reaction by arranging catalyst material in support still more efficiently. Distributing and arranging the catalyst material which supplies a direct reaction raw material, oxygen, etc., for example into support, and is made to react by the catalyst interface as operation of the catalyst material which the above-mentioned support was made to support and which support was made to support at the reaction place in a reaction container etc. is raised. When using support, catalyst material adjusts quantity etc. suitably so that the amount of the catalyst concerned which usually uses all when not using for a reaction place in the reaction may exist. Moreover, about distribution of two or more catalyst material, and arrangement, even if a mutual magnetic field influences, it considers as distribution of catalyst material in which the required gradient magnetic field is formed, and arrangement. Moreover, what fixed the catalyst to the magnet material which has not been magnetized probably can be distributed in the support matter, and it can arrange, and can also consider as the catalyst material in which you made it magnetized by applying a magnetic field with an electromagnet etc. after that, and the suitable gradient magnetic field was formed, and the chemical reaction equipment which has arranged this catalyst material further.

[0012] The chemical reaction equipment of this invention is characterized by having the catalyst material which the above-mentioned support was made to support. Although the chemical reaction equipment of this invention has the usual reaction container, a reaction feeding means, a resultant recovery means, etc., there is especially no limit in these. Arrangement of the catalyst material which the support in chemical reaction equipment was made to support etc. is suitably set up so that it may become the above-mentioned operation.

[0013] The catalyst material of this invention and the chemical reaction equipment using this have more effective magnetic susceptibility to the chemical reaction which decreases more greatly before and after a reaction.

[0014]

[Example] Next, with reference to a drawing, it explains to a detail further per example of this invention.

Example 1 drawing 1 is the explanatory view showing one example of the catalyst material of this invention. Drawing 1 (a) indicates the organic compound 5 of the front face to be the catalyst material 1 which it adhered [ material ] and made the catalyst 2 fix to the front face of the enveloping layer 4 which covers a permanent magnet 3 with a sectional view, and drawing 1 (b) is a graph which shows typically the reinforcement H of a magnetic field and the relation of a location X to the catalyst material 1. Although the thing to which the thin film-like catalyst 2 was made to adhere was shown in drawing 1, the configuration of a catalyst may be granular \*\*, and may distribute and adhere on an enveloping layer. The X-axis of the graph of drawing 1 (b) is the distance from the interface of a magnet 3 of the vertical direction of drawing 1 (a), drawing 1 (a) and drawing 1 R> 1 (b) correspond about this distance, and the steep gradient magnetic field which magnetic field strength increases has occurred as are shown in drawing and a catalyst 2 and an organic compound 5 are approached.

[0015] As what shows the magnetic-field-strength distribution near [ above-mentioned ] the catalyst interface, the thickness of neo MAKKUSU (a trade name, the Sumitomo Special Metals Co., Ltd. make, neodium-iron-boron system) shows 2cm long, the thing of a 3cm wide rectangular parallelepiped, and the measurement result of the magnetic-field-strength distribution of thickness of 2cm long, the thing of a 3cm wide rectangular parallelepiped, and two kinds of permanent magnets by 3cm to drawing 2 by 1cm. N pole in about three-permanent magnet magnetic-field-strength measurement, the south pole, and X shaft orientations were shown in drawing 2 (b). The zero of the X-axis is the core of a magnet side (top face by the side of magnetic N pole). As for 1cm and drawing 2 (Ha), the thickness of a magnet 3 of the drawing 2 (\*\*) is location distribution of magnetic field strength in case thickness is 3cm. Magnetic field strength H is decreasing rapidly as it keeps away from the front face of a permanent magnet 3 in any case. the permanent magnet 0.082T2/cm (8.2kG2/cm) and whose thickness are 3cm in the permanent magnet whose thickness of the magnetic field strength near the front face of a permanent magnet, the product of inclination, and H (dH/dX) is 1cm -- about -- it is 0.24T2/cm (about 24 kG(s)2/cm). These values are almost comparable as the value of the gradient magnetic field obtained with an electromagnet. Since the thickness of the sensor of a gauss meter was 1mm, exact measurement of the magnetic field strength in the location very near a permanent magnet front face was impossible, but since magnetic field strength (H) becomes the inverse number of the n-th power of the distance (X) from a magnet (n is generally 1-3 although based also on a magnetic configuration), it is thought that it is an in practice larger value [ near the pole on the front face of a magnet ].

[0016] Next, when measured also about the case where each permanent magnet is covered with a polyethylene film with a thickness of 0.03mm, the result which is not different from the drawing 2 (\*\*) and (Ha) was obtained. Therefore, it turns out that the steep gradient magnetic field shown to the drawing 2 (\*\*) and (Ha) near the catalyst front face exists line of magnetic force in it when such a catalyst is made to adhere on the thin film which may be penetrated mostly like [ when particles such as platinum and titanium oxide, are made to distribute and adhere on this polyethylene film ] the catalyst material shown in drawing 1.

[0017] When there is the drawing 2 (\*\*) or (Ha) a gradient magnetic field shown, as the arrow head showed in drawing 1 (a), the matter of paramagnetisms, such as oxygen, is drawn on a catalyst front face (a catalyst and interface of an organic compound), and the operation of the gradient magnetic

field where the matter of the magnetism of water, a carbon dioxide, etc. will be eliminated from a catalyst front face itself is understood also from the publication of the specification of patent No. 2034895. Supply of the oxygen gas of a paramagnetism required for reactions, such as oxidation reaction, will be promoted by this, the chemical reaction to which magnetic susceptibility decreases will be promoted on a catalyst front face, and a reaction will be controlled so that the chemical reaction which magnetic susceptibility increases with reactions, such as a reduction reaction, is controlled.

[0018] Location distribution of the magnetic field strength in the case of having arranged two catalyst material of this invention using a cylindrical permanent magnet in the secondary example is shown. The drawing 3 (\*\*) is the explanatory view showing arrangement of two permanent magnets 3 (neo MAKKUSU, the diameter of 3mm, height of 2mm). When a permanent magnet was small, since measurement of location distribution of exact magnetic field strength was very difficult, it calculated about the magnetic-field-strength distribution in the case of two cylinder-like permanent magnets separating 5mm, and existing shown in drawing 3 (b). A Y-axis is the location of the height direction and the X-axis is the location of a Y-axis and a perpendicular direction. Drawing 3 (b) is a graph which shows the magnetic field strength H near the permanent magnet, and the relation of a location X, and is distribution of the magnetic field strength in Y= 1.5mm. Steep gradient magnetic field 0.31T2/cm (31kG2/cm) occurs near the permanent magnet 3. For example, the magnetic attraction which acts on oxygen gas on this magnet front face estimates it as 46microN/cm3 (4.6 dyne/cm3) from a formula (1). The result which does not change even if it covers this cylindrical permanent magnet with a polyethylene film with a catalyst thickness of 0.03mm was obtained.

[0019] Example 3 drawing 4 is the sectional view having shown typically the condition of having made support supporting the catalyst material which is other examples of this invention. The permanent magnet 13 in the catalyst material 11 is a ball type thing, and has the enveloping layer 12 which contains a catalyst on a front face. This catalyst material 11 is distributed and supported in support 14. Support 14 is the matter porous, for example, and the matter and resultant which participate in a chemical reaction can move in the inside of it. The sectional view which expanded the part showed the condition that many granular catalyst material was distributing in support in drawing 4. The enveloping layer 12 which chose suitably the thickness of the particle size and the amount of a catalyst, and an enveloping layer etc., and formed it so that line of magnetic force might be penetrated did not have a bad influence on the gradient magnetic field which a permanent magnet forms, and the steep gradient magnetic field was similarly formed near the catalyst interface with examples 1 and 2 having shown. In addition, the catalyst material which has the supply means of a reaction container besides support and catalyst material or a reaction raw material and the recovery means of a resultant, and the above-mentioned support was made to support created what is filled up into a reaction container and supplies a reaction raw material, oxygen, etc. directly into support as an example of the chemical reaction equipment using the catalyst material which the above-mentioned support was made to support.

[0020]

[Effect of the Invention] The catalyst material of this invention can generate easily a gradient magnetic field and a steep gradient magnetic field, can promote a catalysis, and can make a chemical reaction perform efficiently especially near [ where it is the completely new way of thinking of combining a gradient magnetic field and a catalyst with a magnet, and a reaction actually advances ] the catalyst interface, as explained above. In this invention, large-scale equipment, a large-scale power source, etc. are not needed, but easily, simple, a steep gradient magnetic field can be generated near the catalyst interface, and the outstanding operation of the ability to make oxidation reaction etc. performing efficiently is done so. Moreover, the catalyst material of this invention and the chemical reaction equipment using this can be constituted in a compact, and practical use in various environments is possible for them.

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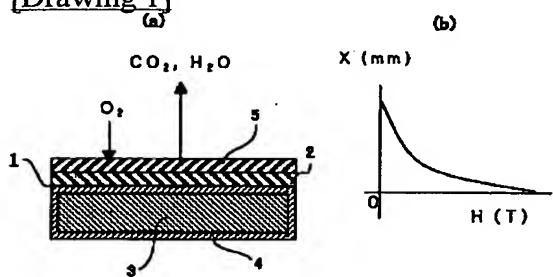
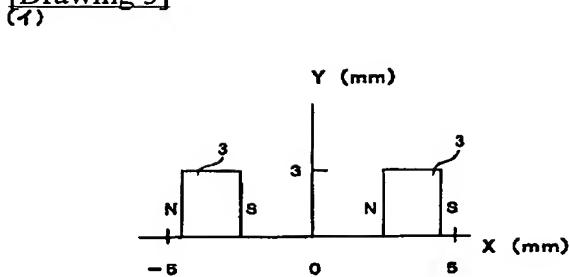
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## \* NOTICES \*

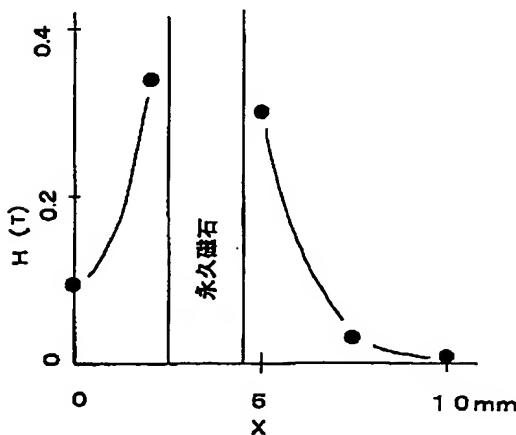
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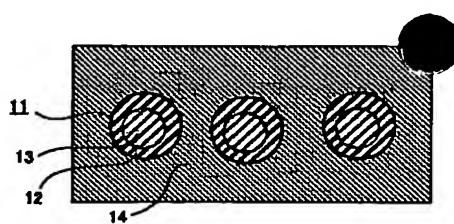
1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

## DRAWINGS

[Drawing 1][Drawing 3]

(□)

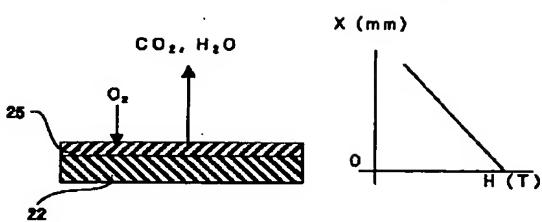
[Drawing 4]



[Drawing 5]

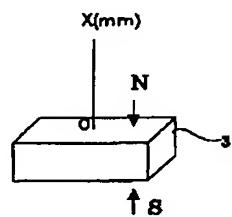
(a)

(b)

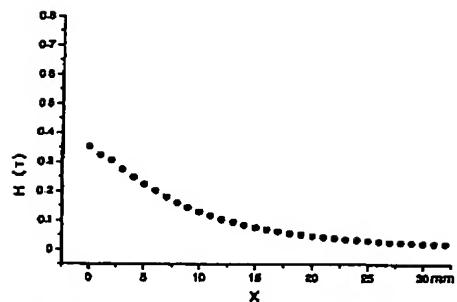


[Drawing 2]

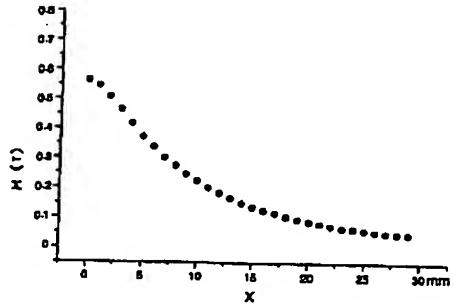
(1)



(2)



(3)



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